

## Chapter 1 – Microbiology

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Millions of Americans become ill each year from eating contaminated food. Even though the United States has one of the best food safety systems in the world, there is still room for improvement within food facility operations. Safety begins with the producers of food and continues through the processors of food, the restaurants and retailers of food, all the way to the consumer.

For example, recent studies suggest that the most common agent in foodborne disease outbreaks is **norovirus**; an organism spread through the following:

- Eating food or drinking liquids that are contaminated with norovirus
- Touching surfaces or objects contaminated with norovirus and then putting your hand or fingers in your mouth, eyes, nose or on ready-to-eat food.
- Having direct contact with a person who is infected with norovirus, for example, when caring for someone with norovirus or sharing foods or eating utensils with them.
- Cleaning up vomit or diarrhea without wearing gloves and mask, or not cleaning and disinfecting thoroughly.

This virus can be spread very easily by bare hand contact with food and has caused death in the elderly and people with compromised immune systems. For example, someone receiving chemotherapy, blood transfusions, kidney dialysis, individuals who are HIV positive, have Crohn's disease, and/or digestive disorders are more likely to become ill than those with healthier immune systems, although anyone can become ill.

**Threats to food safety are caused by hazards that are categorized as physical, chemical or biological.**

**Physical hazards** tend to be sharp or hard objects found in food, whether naturally occurring or introduced after the fact. They include bones, crustacean shells, fruit pits, seeds, packaging, fingernails, fragments of glass, metal, wood, plastic and so on. It is best to avoid the introduction of physical hazards to food where possible and removing them before they find their way to consumers. Injury, choking and death are all outcomes associated with physical hazards.

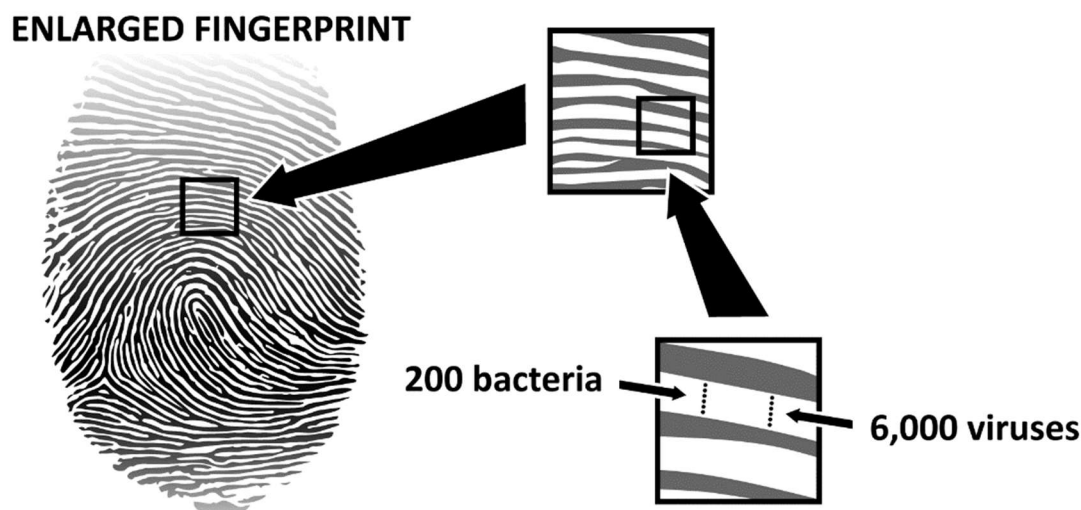
**Chemical hazards** are usually in solution and cannot be seen. This includes those chemicals found in cleaning solutions, sanitizing mixes, and as part of lubricant or oil used in machines such as pasta makers, dough mixers, etc. Chemicals are also found naturally occurring in utensils and containers. Therefore, it is important to use food grade containers only and to use them as directed. Others may include food coloring or additives, pesticides, and toxins. Some species of mushrooms are toxic, and mycotoxins (produced by fungus) are sometimes found in foods like barley, wheat, peanuts, alcoholic beverages and hard cheeses.

**Biological hazards** include **bacterial, viral and parasitic** organisms that cause illness.

**Parasites** involved in most outbreaks are very small and cannot be seen with the unaided eye. Many of these organisms can also be transmitted by water, soil, or person-to-person contact. Occasionally in the U.S., but often in developing countries, a wide variety of helminthic roundworms, tapeworms, and flukes are transmitted in foods such as:

- Undercooked fish, crabs, and mollusks.
- Undercooked meat; raw aquatic plants such as watercress.
- Raw vegetables that have been contaminated by human or animal feces.

**Bacteria and viruses** are extremely microscopic. It would take millions of bacteria to produce a colony the size of the period at the end of this sentence. This many bacteria are **more than enough** to cause many people to become seriously ill. The following example illustrates how small bacteria and viruses are relative to a person's fingerprint.



### SOURCES OF BACTERIA

Bacteria are **everywhere** in our environment. Most are harmless. Some are beneficial and are used to make foods, such as cheese. Others are spoilage organisms that sour and rot our food. A few become a threat to our health when they grow and reproduce. Sources of these bacteria are as follows: soil, water, air, dust, edible plants and plant products, animals and animal products, the intestinal tracts of humans and animals, employee's hands and contaminated food utensils and equipment.

### BACTERIA IN FOOD

A common misconception is that food is free of bacteria that cause foodborne diseases when it reaches the establishment or after processing. The following information suggests otherwise:

**Red Meats.** Concentrations of two types of foodborne disease organisms were found in 28% of pork sausage. Fresh ground beef in a recent study was found to contain three types of foodborne disease organisms: *E. coli* O157:H7, *Salmonella*, and *Campylobacter*.

**Poultry.** Poultry represents an important source of foodborne disease organisms. In one study, 90% of the market-ready chicken and turkey were contaminated with foodborne disease bacteria. In another study, more than half of the poultry samples harbored two types of foodborne disease bacteria: *Salmonella* and *Campylobacter*.

**Seafood.** The incidence of foodborne disease organisms in shellfish depends greatly upon the quality of water from which animals are harvested and handled. In one study, 33% of the seafood tested positive for organisms of salmonellosis. (Viruses, while different from bacteria, are also transmitted through seafood. Another study found that 47% of clams, mussels, and oysters tested were positive for enteroviruses.)

**Dairy Products.** Milk is lower risk because it is pasteurized. However, post-pasteurization contamination and adding ingredients to milk increases potential for outbreaks. Twenty percent of some cheeses are contaminated with disease bacteria. Unpasteurized dairy products present greater risk. Raw milk tested positive for a common disease organism in 48% of the samples taken.

**Deli Foods.** In a recent survey, more than 95% of retail salads (chicken, egg, ham, macaroni, shrimp, etc.) were contaminated with low levels of a common foodborne disease organism. 60% of sandwiches were found to have been contaminated to some extent.

**Dry Products.** In a survey of dry sauce and gravy mixes, soup mixes, spaghetti sauce mixes, and cheese sauce mixes, 18% were contaminated with foodborne disease organisms.

**Grains.** Grains and granary products are commonly contaminated with bacteria. In one study, 100% of raw rice was contaminated with a foodborne disease organism.

**Bakery Products.** The surfaces of freshly baked bread products are practically free of microorganisms, but they are subject to contamination from the air during cooling and during handling. Filled pastries present much greater risk.

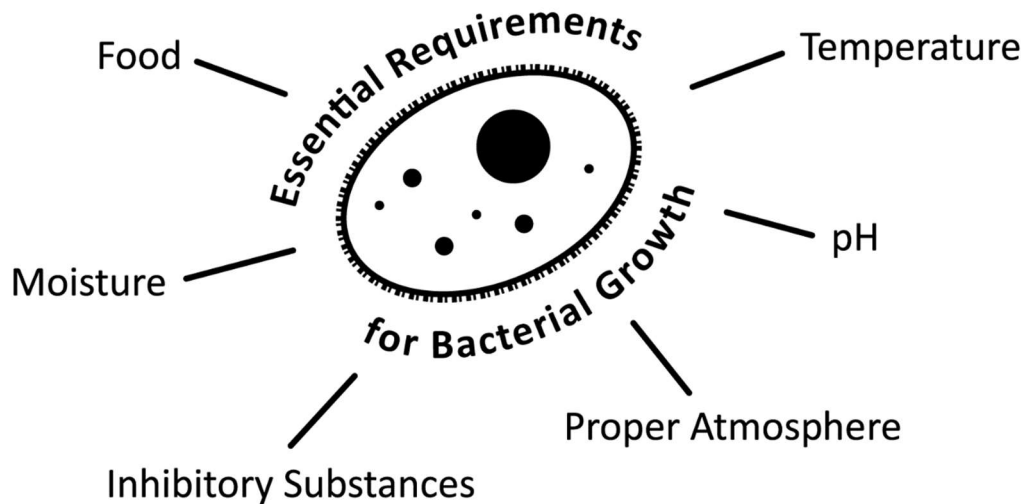
**Vegetables.** Raw vegetables are commonly contaminated with bacteria from the soil. For example, botulism-causing bacteria were found in 12% of frozen spinach in one study. In another study, 46% of raw vegetables were contaminated with another foodborne disease organism. In another study, 26% of the fresh potatoes and 30% of fresh radishes tested positive for *Listeria* organisms.

## **HUMAN BACTERIA**

Another common misconception is that healthy employees do not harbor bacteria. Humans have their own natural population of bacteria (part of the normal flora) and some are the variety that cause foodborne diseases. Most people are carriers of bacteria that cause *Clostridium perfringens* food poisoning. Also, 30% to 50% of the population has staphylococcal food poisoning organisms in their nasal passage or on their skin. Of course, sick employees are carriers of substantial numbers of organisms that cause disease.

## **FACTORS INFLUENCING BACTERIAL GROWTH**

Bacteria have specific nutritional and environmental needs to survive and reproduce. They are as follows: Food, moisture, proper atmosphere, pH, temperature, and inhibitory substances.



**Food.** Bacteria have various food preferences. Those of public health concern will thrive on the same kinds of food that we like to eat.

**Moisture.** There must be adequate moisture for bacteria to grow. The amount of moisture needed is defined by the term water activity ( $a_w$ ). Fresh beef with a high  $a_w$  (0.99) will support rapid bacterial growth. However, cured beef jerky with a lower  $a_w$  (less than 0.85) will not.

**Atmospheric Requirements.** Some bacteria grow rapidly only in the presence of free oxygen; others require the absence of oxygen; many grow in both atmospheres and other bacteria may have special atmospheric requirements. Cooking drives off oxygen; stirring and mixing foods will introduce oxygen.

**pH.** The pH of the bacteria's environment is a measurement of the degree of acidity or alkalinity. The scale is 0 - 14. Most foods occupy the pH scale from 2.3 (which is acidic) to 8.0 (which is slightly alkaline). A pH of 7 is neutral. Most bacteria of public health concern grow best at pH values between 4.6 to 7.5. Examples of food pH are as follows (in **decreasing** order of acidity): lemons, 2.3; vinegar, 3.0; tomatoes, 4.2; bread and ground beef, 5.5; ham, 6.0; corn, 6.3; chicken, 6.4; milk, 6.5; fish, 6.8; pure water, 7.0; and egg white, 8.0. Mixing foods of different pH changes the pH of the mixture.

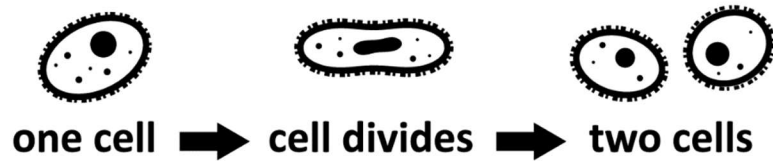
**Temperature.** Some spoilage bacteria grow best at refrigeration temperatures. Others grow best at temperatures above 120°F. Those of public health concern grow best between 60° and 120°F.

**Inhibitory Substances.** Bacterial growth may be slowed, stopped or inhibited by substances produced by the bacteria itself, or ingredients naturally present in the food or added during food processing. Those same substances or ingredients could also enhance the growth of a different bacteria. For example, ham can be treated with a salt concentration to inhibit the growth of spoilage bacteria. However, that same condition supports the growth of common food poisoning bacteria.

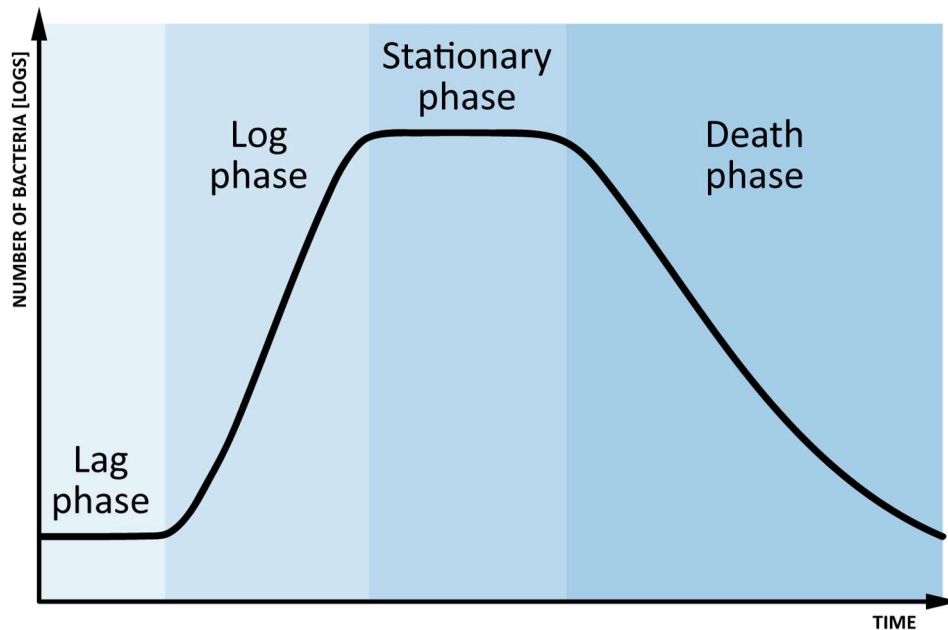
It is essential to understand these factors and what influences bacterial growth, or why some foods support bacterial growth in one form but not in another.

## **BACTERIAL GROWTH**

Bacterial growth refers to the **increase in number** of organisms. This is accomplished by cell division, whereby the bacterial cell splits to form two cells.



Bacterial growth is described in four phases and can be very rapid, but not until conditions are just right. It is important to understand what takes place at each phase of the bacterial growth curve.



**Lag Phase.** When bacteria are introduced to food, there is an adjustment or lag period. During this time, there is considerable biochemical activity but no increase in the number of cells. The lag phase can range from a few hours to days.

**Log Phase.** When conditions are right, rapid growth commences. This is called the log or logarithmic phase because the bacteria double their number by cell division, some at a rate of every 20 minutes. It is generally not appreciated until it is graphically illustrated, like in the following example:

Example of Logarithmic Growth Rate Time	Number	Total Time	Number
Start	216	2'20"	27,648
20"	432	2'40"	55,296
40"	864	3'00"	110,592
1'00"	1,728	3'20"	221,184
1'20"	3,456	3'40"	442,368
1'40"	6,912	4'00"	884,736
2'00"	13,824	4'20"	1,769,472

The above example demonstrates how starting with 216 bacteria and with a 20-minute doubling rate, after 4 hours and 20 minutes there would be over 1 million bacteria.

**Stationary Phase.** After a period of rapid growth, bacteria numbers reach the leveling-off stage as nutrients are used up and waste accumulates. Foods at this level and beyond are usually "spoiled" because of the bacterial activity and are generally unacceptable from a purely organoleptic viewpoint. (Referring to flavor, aroma, and appearance.)

**Death Phase.** At this point, the food is no longer suitable for supporting growth and the bacteria die.

## **INTERESTING INFORMATION ABOUT FOODBORNE DISEASE CAUSATIVE AGENTS**

### **BACTERIA**

- No foodborne disease bacteria will grow when temperatures reach freezing, but many survive. Most bacteria grow slowly at refrigeration temperatures (41°F or less), and growth rate increases with increased temperature. Rapid growth occurs at room temperature (about 70°F). Fastest growth for most bacteria occurs between 90° and 100°F. Several bacteria types survive higher temperatures, and a few can tolerate boiling for a brief period of time.
- As few as two salmonellosis bacteria in a teaspoonful of milk are sufficient to cause the disease. To cause some other foodborne diseases, as many as five million or more bacteria in a teaspoonful may be required. Some bacteria concentrations in contaminated food may be 50 million or more per teaspoonful.
- Some foodborne disease bacteria form spores (protective shells) when conditions are not suitable for growth. These bacteria can live for a long time in the spore stage in dry conditions, at adverse temperatures and during exposure to some chemicals. When conditions are suitable again, the bacteria grow.
- Some foodborne disease bacteria do not grow very well when other competitive bacteria (such as spoilage bacteria) are present. Improperly cooking food might kill spoilage bacteria in the food, but may ultimately contribute to the growth of foodborne disease bacteria that are not killed until a higher temperature is reached. For this reason, it is essential that foods are cooked to the proper temperatures to eliminate the pathogenic bacteria.
- Some bacteria produce a toxin (poison). Cooking the food may kill the bacteria without destroying the toxin. However, botulism toxin can be destroyed by boiling for at least 10 minutes.

### **VIRUSES**

- Unlike bacteria, viruses do not grow in food. Food only serves as a "middle step" from the source of contamination to the consumer. In this instance, humans are the primary contamination source, either directly or indirectly.
- The two viruses commonly attributed to foodborne disease outbreaks are hepatitis A and norovirus. Contaminated shellfish, uncooked foods and foods contaminated after cooking have contributed to a considerable number of hepatitis A outbreaks. Outbreaks of norovirus in uncooked foods are

increasing throughout the nation. It is more resistant to destruction than hepatitis A virus.

- Norovirus has been the cause of several disease outbreaks associated with cruise ships but it is more commonly found in restaurants from bare hand contact with ready-to-eat foods.
- Norovirus is **extremely** virulent and contagious, meaning that it can make someone very sick in a short timeframe and it is very easy to spread to another person. Symptoms include nausea, vomiting and diarrhea. A worker in a food establishment with these symptoms should not be allowed to work in an area where he or she might have direct contact with food or clean and sanitized work surfaces. Outbreaks of norovirus have been associated with a person simply being in the same room where someone else was ill – even 1 or 2 **days** after the ill person left the room!

### **PARASITES**

- The most common parasite involved in foodborne disease outbreaks is the trichinosis nematode (a species of roundworm that can be found in pork). The disease is acquired from consuming raw or improperly cooked meat.
- The Anisakid is another roundworm associated with many species of fish (sea bass, ocean perch, rockfish, cod, salmon, and tuna). There is an increased risk of illness (anisakiasis) because of a growing interest in eating sushi, sashimi, ceviche, etc.
- Other less common parasites that are found in or transmitted by food are the protozoans that cause giardiasis and amebiasis. Infected persons transmit the organisms to food by failing to adequately wash their hands after using the restroom.
- Cyclospora is a parasite that causes infection when people consume it in food or water. It is a growing concern in developing countries but makes it way to the U.S. through food imports such as raspberries, basil, lettuce and other fresh produce. Practicing good hand washing in addition to washing fresh fruits and vegetables is the only preventive measure for food service workers.

### **CHEMICALS**

- Food accounts for 80-90% of the total human exposure to most chemicals from environmental sources. Fish poisoning (ciguatoxin and scombrototoxin) accounts for most of the reported outbreaks. Scombroid poisoning is most often a result of a naturally formed toxin produced in fish that have been improperly refrigerated.
- Heavy metal poisoning occurs frequently when acid foods (such as lemonade) and carbonated beverages come in contact with such heavy metals as copper, zinc, antimony and cadmium. One example of this is a store that served juice during a grand opening sale. Shortly after drinking the juice, several people became violently ill. The juice was served in a galvanized container and the acids in the juice reacted with the metal, causing heavy metal poisoning.
- Proper storage of cleaning chemicals and ensuring proper temperatures of foods at all times will help to prevent the possibility of “food poisoning” from chemicals.

## **PREVENTION**

- The simple way to prevent these types of organisms from getting into food is to thoroughly **wash your hands!** Chapter 6 of this manual describes how and when to wash your hands. Some bacteria and viruses are so small that hand washing alone might not be enough to prevent these organisms from getting into food. Therefore, once your hands have been thoroughly washed, you should also avoid bare hand contact with ready to eat foods. These are foods that will not be cooked before they are served. Examples are deli meats, cheese, lettuce, tomatoes, breads, etc. You must always use some type of device such as tongs, forks, spoons, or gloves to avoid touching these types of foods with your bare hands. Even after you have washed your hands, you still must not touch these types of foods with your bare hands.
- Properly cleaning and sanitizing food contact surfaces such as counter tops, cutting boards, and other work surfaces will also help to prevent harmful bacteria and viruses from getting into food. Chapter 7 of this manual will describe proper techniques to wash and sanitize surfaces.

## **SUMMARY**

- Bacteria are so small that thousands in one spot cannot be seen with the unaided eye.
- Bacteria are everywhere. Most are harmless, some are beneficial and a few cause diseases.
- Proper handwashing **and** avoiding bare hand contact with foods that will not be cooked are a simple way to prevent harmful bacteria and viruses from getting into the food.
- Fresh foods may contain disease-causing bacteria.
- Three of the most essential requirements for bacterial growth are food, moisture and temperature.
- Bacterial growth is accomplished by cell division.
- When conditions are just right, bacterial growth can be very rapid and in a few hours the number can be in the millions.
- Foodborne disease bacteria will not grow at freezing temperatures, but some grow at refrigeration temperatures; many grow at room temperature, and the greatest growth is between 90° and 100°F.
- With some foodborne diseases, ingesting only two organisms is enough to cause illness. For others, thousands or millions of organisms are required.
- Some bacteria form spores and can live a long time when growth conditions are not just right.
- These spores can release a toxin into the food once conditions are right.
- Viruses do not grow in food. Humans are the source of viral contamination.
- The trichinosis nematode is an important parasite. It is found in improperly cooked meat.
- Improperly refrigerated fish can become toxic.
- Lemonade in a copper container can become toxic.
- A food worker who is experiencing nausea, vomiting, diarrhea, fever with sore throat, or jaundice must be restricted in his or her job duties until these symptoms subside.